(12) UK Patent Application (19) GB (11) 2 046 530 A

(21) Application No 8008141
(22) Date of filing 11 Mar 1980
(30) Priority data
(31) 7908621
(32) 12 Mar 1979
(33) United Kingdom (GB)
(43) Application published 12 Nov 1980
(51) INT CL³ H01Q 1/38
(52) Domestic classification H1Q KA
(56) Documents cited GB 1232997
(58) Field of search H1Q

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(54) Microstrip antenna structure

(57) A microstrip antenna which allows integration of the antenna radiator and its associated microwave components on to a common microstrip board having a relatively high dielectric constant, eg alumina, the antenna being linked to associated components by a feed-line formed on the board. Such dielectrics are normally unsuitable for forming microstrip antennas because the wave is too tightly bound. The present antenna comprises a conducting sheet radiator 15 spaced above the level of the line 12 by a dielectric layer 16 whose dielectric constant is substantially less than that of the board itself. The radiator may comprise a plurality of alternate layers of such conducting sheets and dielectric layers of the same or slightly different dimensions to give increased bandwidth. Coupling between the radiator and the feed-line can be effected in several ways, suitably by forming on the board a sheet resonator connected to the feed-line, which resonator underlies the lowermost dielectric layer.

Fig.2.

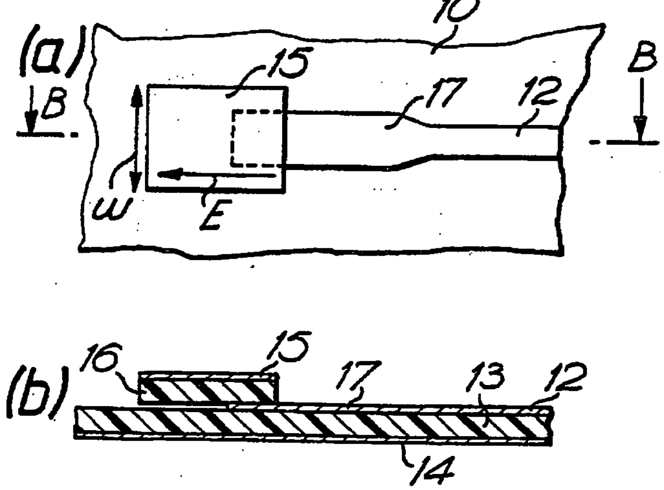

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Fig.1.

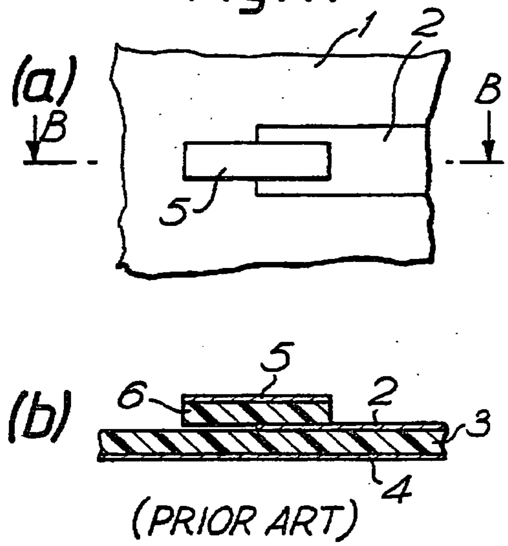


Fig.2.

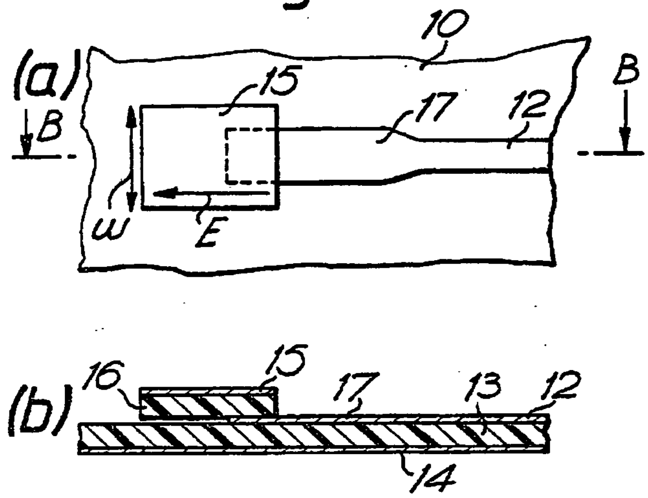


Fig.3.

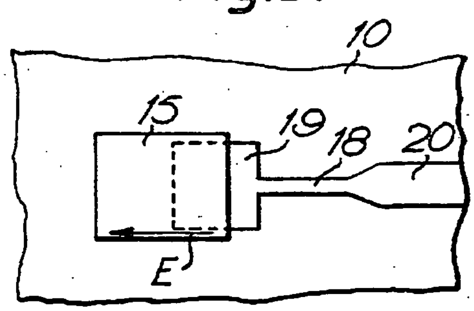


Fig.4.

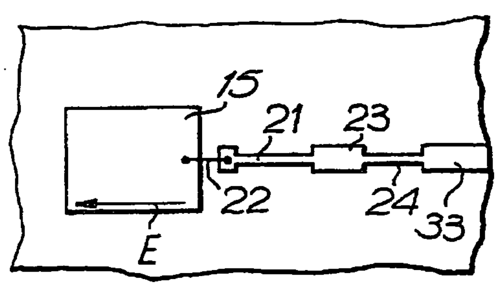
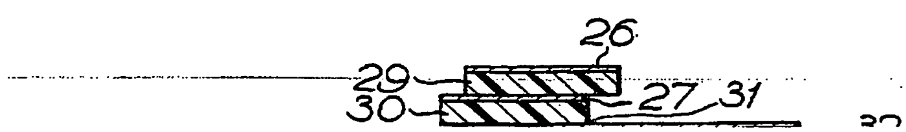


Fig.5.



SPECIFICATION

Improvements in or relating to microstrip antennas

This invention relates to microstrip antennas and provides forms of antennas enabling an antenna and its associated microwave circuits to be integrated on to a common substrate.

It is known to form an antenna as a flat dipole which partially overlies the end of a microstrip feed-line, being separated from the upper conductor thereof by a layer of dielectric material. Such a structure is described in US Patent No 4,054,874 to Oltman, and in a paper by Oltman entitled "Electromagnetically coupled microstrip dipole antenna elements", 8th European Microwave Conference, Paris, October 1978, pp281-285. The present invention provides modified forms of such antennas which have unique and valuable properties.

With the increasing compactness of modern microwave systems, it is becoming desirable to integrate the antenna and the circuit components (such as power dividers, filters, circulators and even active devices) on to a common substrate. There is a conflict however, in the transmission properties required for circuits components on the one hand and antennas on the other; circuits need a tightly bound wave with little radiation and surface-wave generation, whereas antennas require a loosely bound wave to allow efficient radiation. Thus circuit components are usually formed on high dielectric-constant substrates ($\epsilon_r \approx 10$) such as alumina, whereas antennas use lower dielectric-constant materials ($\epsilon_r < 3$), such as Polyguide (an irradiated polyolefin), Duroid (glass-loaded PTFE)or Rexolite (polystyrene). The antenna-to-circuit interface then generally consists of a connector or cable, which introduces constructional difficulties and, especially at higher frequencies, considerable loss.

It has now been found that the structure disclosed by Oltman can be modified to provide a form suitable for use in in such integrated construction with particular advantage.

According to the present invention a microstrip antenna suitable for the latter purpose comprises:

a microstrip board having a condcutive feed-line on a first side thereof and a conductive surface on its second side, the dielectric material between said line and surface being relatively high dielectric constant;

a radiator comprising a conducting sheet on a first side of a layer of dielectric material of relatively low dielectric constant whereof the second side is in contact with said first side of the microstrip board;

and means for coupling said radiator to said conductive feed-line.

For example the material of relatively high dielectric constant may be alumina, and the material of relatively low dielectric constant may be comprise a polymer as in Polyguide, Duroid or Rexolite mentioned earlier.

The radiator may be secured to the microstrip board by a suitable adhesive such as loctite 307 or Avdelbond (cold-setting), or 3M Bonding film (hot-curing), or by a bolt or equivalent fixing. The radiator may be a resonant radiator.

The coupling means may comprise the end of the line itself arranged to partially underlie said layer of dielectric material; or may comprise a sheet resonator formed on said board at the end of said line and arranged to wholly or partially underlie said layer of dielectric material; or may comprise a loose conductor, eg a wire or tape, connected between the end of said line and the conducting sheet on the first side of said layer of dielectric material.

The above-defined form of antenna enables the circuit components to be found on the microstrip board resulting in tightly bound waves, while the waves in the conducting sheet of the radiator are loosely bound, as required.

It has also been found that a modified form of radiator having greater bandwidth than the simple form described by Oltman can be provided by using a plurality of layers of conducting sheet separated by dielectric material, instead of the single layer disclosed by Oltman.

Accordingly the aforesaid radiator may comprise alternate layers of dielectric material of relatively low dielectric constant and of conducting sheets superimposed upon another with a conducting sheet uppermost and the lowermost layer of dielectric material in contact with said first side of the microstrip board, there being at least two layers of said material and two said sheets.

The sheets may all be the same size or slightly different sizes, and their adjacent underlying layers may all have the same thickness or different thicknesses.

To enable the nature of the present invention to be more readily understood, attention is directed, by way of example, to the accompanying drawings wherein:

Fig 1(a) is a plan view, and Fig 1(b) a sectional view on the line B-B in Fig 1(a), of a known form of antenna.

Fig 2(a) is a plan view, and Fig 2(b) a sectional view on the line B-B in Fig 2(a), of an antenna embodying one aspect of the present invention.

Figs 3 and 4 are plan views similar to Fig 2(a) showing two alternative feed line-to-radiator coupling arrangements.

Fig 5 is a sectional view similar to Fig 2(b)of an antenna embodying a further aspect of the present invention.

Figs 1(a) and (b) show a form of antenna described by Oltman in the aforementioned publications. It comprises a microstrip board 1 having a conductive feed-line 2 formed on a first side of a dielectric layer (the substrate) 3 which has a conductive surface 4 (the ground-plane) on its second side. The antenna proper comprises a conductive sheet dipole 5 which overlies the line 2 and is spaced from its plane by a dielectric layer 6. (It will be appreciated that all the Figs are essentially diagrammatic for clarity, and that the "gap" shown between layers 3 and 6 is due to

The drawing originally filed was informal and the print here reproduced is taken from a later filed formal copy.

the exaggerated thickness of conductor 2 and in practice would be filled with the adhesive, where used). The increased distance of the dipole 5 from the ground-plane 4 of the board 1 effected by the layer 3 gives *inter alia* increased radiation efficiency and bandwidth, as explained by Oltman. The coupling between the dipole and the line depends on the amount of overlap between them, which can be adjusted for optimum matching.

In Oltman's descriptions no reference is made to any difference between the dielectric constants (ϵ_r) of layers 3 and 6 and it is evidently assumed that these will be similar. It has now been found that such increased separation of the radiator from the ground plane has particular advantage where the layer 3 has a relatively high ϵ_r, eg where layer 3 is alumina, because layer 6 can be a different material having a lower ϵ_r. Thereby, as explained in the present introduction, the waves associated with the feed-line and other components formed on the board will be tightly bound, whereas the wave associated with the radiator will only be loosely bound, as is desirable. Moreover, it can be shown that at a fixed frequency and (resonator width) - to - (substrate height above the ground plane) ratio, w/h, reducing ϵ_r will increase the bandwidth of the resonant radiator.

In the embodiment of Fig. 2 a microstrip board 10 has an alumina dielectric ($\epsilon_r \approx 10$) and a conductive ground-plane 14 of copper sheet. A copper-sheet feed-line on the other side of layer 13 (assumed to lead from other circuit components formed on board 10 but not shown) has a portion 12 whose impedance (z) matches that circuit (usually 50 ohms), leading to a lower-z portion 17 which partially underlies a known form of dipole resonant radiator consisting of a rectangular copper sheet 15 and matches the line thereto. Sheet 15 is spaced from the plane of portion 17 by a dielectric layer 16 of relatively low ϵ_r, eg items 15 and 16 can be a piece of Polyguide ($\epsilon_r <$ 3) stuck to the board 10 by a suitable adhesive. The average value of ϵ_r between ground plane 14 and sheet 15 is thus effectively reduced, giving increased bandwidth. The direction of the radiated electric vector is indicated by the arrow E in Fig. 2(a). The rectangular shaped sheet 15 is preferred to the narrow dipole 5 described by Oltman (Fig 1) because it can be shown that a fixed frequency and for a given ϵ_r, increasing the width W (ie normal to vector E, see Fig 2(a)) increases the bandwidth.

Fig 3 shows a modified arrangement for coupling the line to the radiator 15. Again the board dielectric 13 (not shown) is alumina and items 15 and 16 suitably Polyguide. The feed-line now comprises a circuit-matched portion 20 leading to a higher-z portion 18 which feeds and matches to a rectangular resonator 19 formed on the alumina. Radiator 15 partially overlies resonator 19, matching being effected by adjusting the width of line portion 18 and adjusting the amount of overlap to give maximum bandwidth. No sectional view is illustrated because of its similarity to Fig 2(b).

In Fig 4 a yet further coupling arrangement is used. Sheet 15 does not overlie either the feed-line or a resonator formed on the alumina but is connected to the line by a soldered wire or tape connection 22 to a high-z portion 21 of the feed-line. Portion 21 is matched to the circuit-matched portion 33 of the feed-line by matching portions 23 and 24. Again no sectional view is shown becuase of its similarity to Fig 2(b) apart from the absence of overlap.

In Fig 5 a further increase in bandwidth is obtained by forming the resonant radiator of a plurality of sheets alternating with dielectric layers and capacitatively coupled to one another. The sheets may be the same size or of different sizes, so long as the sheets resonate at slightly different frequencies; it is found that even when they are the same size their resonant frequency varies with height above the board 10. Fig 5 shows two such sheets 26, 27 alternating with dielectric layers 29, 30, the last of which is stuck to and partially overlaps a resonator 31 fed by a feed-line in the manner of Fig 3. The dielectric 32 is alumina and the layers 29, 30 are of relatively low ϵ_r as in Fig 3, e.g. Polyguide is again suitable. The sheets 26, 27 (and their associated layers 30, 31) are aligned symmetrically with respect to the axis of the feed-line, but their positions relative to one another and to the resonator 31 in the direction of that axis are adjusted to give the maximum measured bandwidth and may therefore appear staggered as shown in Fig 5. The bandwidth increases with the number of superimposed sheets.

The following Examples of results obtained with some embodiments of the present invention including comparisons with the bandwidths obtained when the radiator is formed as a single resonator formed on the substrate of the microstrip board itself, ie in the plane of the feed-line and conductively connected thereto in the manner of resonator 19 in Fig 3. In all Examples the substrates of the microstrip boards (items 13 and 32 in the Figs) are 0.5mm thick alumina and the conducting sheets and dielectric layers (items 15, 16 and 25-30) are made of Polyguide. All sheets are aligned with their longest edges parallel to the feed-line axis and their positions in the direction of that axis adjsted for maximum bandwidth.

The bandwidths given are defined for greater than a 10 dB input return loss.

Example 1

Coupling arrangement: 30 ohm line as in Fig 2.

Radiator: Single conducting sheet on 0.80 mm thick Polyguide (as Fig 2) 8mm x 8mm; resonant frequency 10.2 GHz.

Bandwidth: 7.2%

Bandwidth of equivalent radiator on alumina substrate: 1%

Ditto on Polyguide substrate: 2%

Example 2

Coupling arrangement: High-z line + 6mm x 5mm resonator on alumina substrate as in Fig 3.

Radiator: Single conducting sheet on 1.6mm thick Polyguide (as Fig 2), 8mm x 5mm; resonant frequency 10.5 GHz.

Bandwidth: 11%

Bandwidth of equivalent radiator on alumina substrate: 1%

Example 3

Coupling arrangement: High-z line + 4.6mm x 4mm resonator on alumina substrate as in Fig 3.

Radiator: Two conducting sheets on 1.6mm thick Polyguide (as Fig 5), one 5 x 6mm (uppermost and staggered towards line as in Fig 5), other 4mm x 6.6mm; resonant frequency 11GHz.

Bandwidth: 21%

Bandwidth of single equivalent radiator on alumina substrate: 1%

It will be noticed that the two-sheet assembly of Example 3 gives almost twice the bandwith of the single sheet of Example 2, the Example being otherwise similar.

Although in all the described embodiments the radiators are of rectangular shape and operate as dipole resonators, the invention is not limited to microstrip radiators of this shape and they need not necessarily be operated in the resonant mode. For example the invention may be applicable to circular radiators, and to circularly polarised radiators of both the resonant and spiral varieties.

An antenna array embodying the present invention may be formed by a plurality of individual antennas as aforesaid whereof the respective radiators are fed in parallel by a corresponding plurality of individual feed-lines as described. An alternative arrangement which may be usable to form an array comprises a plurality of individual antennas as aforesaid whereof the radiators are coupled to a single feed-line at spaced locations along the line, suitably by increasing the line-width at said locations to form resonators which couple to the overlying radiators in a manner similar to that of Figs 3 and 5.

The present invention is to be distinguished from the arrangement shown in US Patent No 4,070,676 to Sanford which discloses microstrip antenna structures comprising a plurality of superimposed conducting sheets separated by layers of dielectric material. However Sanford, like Oltman, does not disclose the use of materials of different dielectric constants for the microstrip board and the separating layers. In Sandford also, the resonant frequencies of the superimposed sheets are far apart so that only a selected sheet is excited by a given input or output signal of corresponding frequency, whereas in the arrangement of the present Fig 5 the resonant frequencies of sheets 26 and 27 are, of course, sufficiently close to give a good Voltage Standing-Wave Ratio over a given band. Furthermore, Sanford describes the feed-line as being directly connected at least to the uppermost sheet (alternatively also to lower sheets). Such an arrangement is unsuitable for use with a high dielectric-constant microstrip board on which the circuit components and antenna are integrated, for which the present invention is particularly suitable as already explained, since with the resulting large gap between feed-line and ground-plane the advantage of tight binding of the wave would be lost.

It will be understood that the use of the term "radiator" in the present Specification does not limit the invention to transmitting antennas, and that the present antennas can, as usual, be used for either transmitting or receiving.

CLAIMS

1. A microstrip antenna comprising:

a microstrip board having a conductive feed-line on a first side thereof and a conductive surface on its second side, the dielectric material between said line and surface being of relatively high dielectric constant;

a radiator comprising a conducting sheet on a first side of a layer of dielectric material of relatively low dielectric constant whereof the second side is in contact with said first side of the microstrip board;

and means for coupling said radiator to said conductive feed-line.

2. An antenna as claimed in claim 1 wherein said coupling means comprises the end of the line arranged to partially underlie said layer of dielectric material.

3. An antenna as claimed in claim 1, wherein said coupling means comprises a sheet resonator formed on said board at the end of said line and arranged to wholly or partially underlie said layer of dielectric material.

4. An antenna as claimed in claim 1 wherein said coupling means comprises a loose conductor connected between the end of said line and the conducting sheet on the first side of said layer of dielectric material.

5. An antenna as claimed in any preceding claim wherein the radiator comprises alternate layers of dielectric material of relatively low dielectric constant and of conducting sheets superimposed upon one another with a conducting sheet uppermost and the lowermost layer of dielectric material in contact with said first side of the microstrip board, there being at least two layers of said material and two said sheets.

6. An antenna as claimed in claim 5 wherein said sheets are substantially all the same size.

7. An antenna as claimed in claim 5 wherein said sheets are of slightly different sizes.

8. A microstrip antenna substantially as hereinbefore described with reference to Figs 2, 3, 4 or 5 of the accompanying drawings.

Printed for Her Majesty's Stationery Office by The Tweeddale Press Ltd., Berwick-upon-Tweed, 1980.
Published at the Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.